WHITE RIVER COUNTYLINE REACH
PRELIMINARY DRAFT MONITORING PLAN
RM 5.0 (8TH ST. E BRIDGE) TO RM 6.3 (A ST. SE BRIDGE)

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Table of Contents

1.0. Project Summary

The Countyline Reach of the Lower White River is bounded by the A Street SE and Burlington Northern Santa Fe (BNSF) Railway Bridges at the upstream end (River Mile 6.3) and the 8th Street East Bridge at the downstream end (RM 5.0), and is so named because it spans the King-Pierce County boundary. Portions of this reach fall within the City of Auburn, City of Pacific, City of Sumner, and unincorporated Pierce County.

King County has two proposed levee setback projects within the Countyline Reach: the Countyline Levee Setback Project on the left bank looking downstream and the Right Bank Levee Setback Project on the right bank looking downstream. The combined result of these projects will be to reconnect approximately 120 acres of floodplain to the White River channel. Both projects involve property acquisition, levee removal and setback, and floodplain enhancement and restoration. Both projects are designed to reduce flood risk, restore natural river processes, reconnect the river to its adjacent floodplain, and improve fish rearing habitat.

The Countyline Levee Setback Project (left bank) is scheduled for construction from May 2014 through November 2015. The Right Bank Levee Setback Project is currently in the conceptual design phase and is scheduled for construction in 2015 and 2016.

1.1. Project Setting

The lower White River is a highly modified system. The White River originates from the Emmons Glacier on Mount Rainier and flows through a relatively higher gradient channel with steeper valley walls before reaching a lower gradient reach where the proposed Countyline Reach levee setback projects are located. The White River historically flowed into the Green River in the City of Auburn. In 1915, the Auburn Wall was built to permanently divert the White River into the Stuck River channel, a substantially smaller distributary channel that flowed to the Puyallup River. The new channel was extensively dredged to accommodate White River flows.

The White River carries a high sediment load due to its origins on an active, glaciated volcano, a steep channel gradient through most of its length, and its erosion through relatively new glacial and volcanic deposits. With a marked decrease in channel gradient and channel confinement downstream of the White River canyon near the City of Auburn, the river naturally deposited sediment to form a broad alluvial fan. Channelization and construction of a confining levee system in the early 1900s in this naturally depositional environment of a broad alluvial fan likely enhanced the vertical rates of sediment accumulation within the channel, the historical response to which was a consistent river management program of gravel extraction to maintain river channel capacity in this Countyline Reach (Herrera 2010). Cessation of gravel removal in the late 1980s probably has in part contributed to channel aggradation within the confines of the levees in the lower reaches of the White River.

The existing levees currently have wetlands behind them that are rarely flooded by the White River. The hydrogeomorphic setting of the wetlands should be riverine due to the role of the White River in shaping the topography. However, atypical wetlands exist at both sites due to the construction of the levees between the wetland and the main river channel, and therefore both wetlands are best classified in their current condition as depressional.

1.2. Project Justification

Flood Risk Reduction

The problems associated with channel aggradation in this reach became increasingly evident during the January 2009 flood event. During this flood, the U.S. Army Corps of Engineers released up to 11,700 cubic feet per second (cfs) from Mud Mountain Dam, as had been done in past flood events. However, flood damage in 2009 along the Countyline Reach of the Lower White River was significantly different than damage during earlier events.

Floodwaters overtopped the right bank (looking downstream) by Pacific City Park and flowed southward through the White River Estates neighborhood, continuing into Pierce County along the floodplain areas of Butte Avenue. Over 100 homes in White River Estates neighborhood, several commercial businesses along Butte Avenue, and the Megan's Court Apartments near the city park experienced flooding of first floor living spaces, office areas, and building crawl spaces. Evacuations of residents occurred along Butte Avenue, south of White River Estates, and many efforts were made by citizens and City of Pacific staff to place sandbags in an attempt to protect residential structures. On the opposite riverbank, floodwaters overtopped into agricultural lands in the City of Sumner and overtopped 8th Street E, also known as Stewart Road SE; a major arterial.

Subsequent investigations have revealed that the channel capacity in the Countyline Reach of the White River has decreased from 25,000 cubic feet per second (cfs) to 8,000 cfs. With no action in this area, the channel is projected to completely fill with sediment in approximately 15 years. This significantly increases the flood risk for commercial, industrial, and residential parcels adjacent to and downstream of the project area. Analyses also indicate that gravel removal would have a relatively minor and short-lived effect on reducing flood water levels in this Countyline Reach, especially compared to those with a setback levee in place (Czuba et al. 2010; King County 2012e). In addition, the 8th Street E Bridge in Sumner which has two in-channel piers and little remaining clearance from its low chord, significantly constricts flows and will be at increased risk of overtopping or failing during high flow events.

Habitat Restoration

The levees and their riprapped banks have changed the way the White River moves and deposits sediment, shortened the river's length, reduced access to side channels and floodplain wetlands, reduced the quality of riparian habitat for fish and aquatic species as well as other riparian wildlife, and reduced the supply of large wood to the active river channel. The lower White River today is relatively simple, consisting primarily of fast-water habitats (referred to as riffles or runs) with very few pools or off-channel habitats. These conditions provide very little cover for juvenile salmon, making the lower river less productive for many species at critical life stages.

The need for rearing and off channel salmonid habitat in this reach of the White River is documented in the Puyallup Watershed (WRIA 10) and Chambers/Clover Creek Watershed (WRIA 12) Salmon Habitat Protection and Restoration Strategy (Pierce County 2008). This report notes:

"The loss of floodplain habitat that is limiting the performance of Puyallup and White River Chinook is due to the channelization and confinement of the river within an extensive system of revetments and levees (flood works) in the mainstems of the Puyallup, White, and Lower Carbon Rivers. Preferred projects in the mainstem areas would protect and restore floodplain habitat such as side channels and backwaters." (Page 17)

The Strategy identifies lack of this type of habitat as a bottleneck in meeting basin-wide recovery goals for Chinook salmon and concludes:

"Levee setbacks and estuarine habitat creation are the most beneficial types of actions needed for recovery of Chinook in WRIA 10." (Page 21)

WRIA 10/12 conducted a levee setback feasibility study in 2008, and the Countyline Levee Setback Project was a highly ranked project for its potential to provide high quality juvenile salmon rearing habitat. The project was also added to the WRIA 10/12 3-Year Implementation List and ranked as having a high benefit to salmon.

1.3. Project Goals and Objectives

The Right Bank Levee Setback Project goals and objectives have not yet been developed, but are expected to be similar to the left bank project. The goals of the Countyline (left bank) Levee Setback Project were written to complement goals in both the WRIA 10/12 Salmon Habitat Protection and Restoration Strategy (Pierce County 2008) and the King County Flood Hazard Management Plan (FHMP, King County 2006). Protection and reconnection of floodplain habitat and fluvial processes is expected to support the productivity of freshwater life stages of salmonids, and floodplain reconnection projects have been identified by the Puyallup/White Watershed (WRIA 10) as the highest priority for lower White River Chinook habitat protection and restoration (Pierce County 2008). Floodplain reconnection and levee setbacks are key strategies in the FHMP for reducing flood risks while working with natural riverine processes. These techniques are also thought to be less costly over time than traditional structural approaches to flood hazard management (King County 2006).

The goals and objectives of the Countyline Levee Setback Project are:

Goal 1
Restore riverine processes and functions to the lower White River and its floodplain within the project area (inside the levees) in order to enhance salmonid rearing habitat, in particular for spring and fall Chinook, coho, and steelhead.

<u>Objectives:</u>

1.1 Allow natural channel movement within the project area by removing and setting back the existing levee along the left bank.

1.2 Encourage the formation of off-channel rearing habitat (pool complexes and side-channels), such as through installation and future natural recruitment of large wood, that will promote the return of the complexity, diversity, and morphology found in an unconstrained floodplain.

1.3 Provide off-channel flood refuge for salmonids by allowing a more natural frequency of inundation of the floodplain complex during flood events within the project boundaries.

1.4 Protect existing mature riparian buffer areas and restore a corridor of mature riparian vegetation within the project boundaries to provide shoreline and stream channel shading, invertebrate prey supply, and large wood recruitment.

Goal 2
Prevent an increase in flood hazards outside of the project area due to this restoration project and, if possible, reduce existing flood hazard.

Objectives:
2.1 Design the project to ensure flood hazards (on private property or public infrastructure) outside of the project area do not increase due to the project.
2.2 Increase flood storage along the length of the project which will also have a net benefit on flood elevations in the immediate vicinity of the project, particularly the right bank.
2.3 Avoid or minimize the need for sediment management actions.

Goal 3
Design and construct a project that best meets the goals and objectives of the project using the most cost-effective means.

Objectives:
3.1 Evaluate individual and collective project components based on cost-effectiveness and ability to achieve the goals and objectives for salmonid habitat (primarily) and flood hazards.
3.2 Avoid or minimize the need for remedial actions (habitat restoration or construction to avoid or repair public damage) by incorporating self-sustaining habitat restoration and flood hazard reduction components in the design.
3.3 Work with landowners to negotiate acquisitions or conservations easements.
3.4 Work with all stakeholders, including the City of Pacific, City of Sumner, and Pierce County, Washington State Fish and Wildlife, the Puyallup Tribe and the Muckleshoot Tribe throughout the project to foster project support and a clear understanding of any needs or issues.

1.4. Project Actions

Because the lower White River is highly modified and constricted, the approach to resolving existing flood risks focuses on increasing flood flow and sediment load capacity. The strategy is two-fold: (1) acquire land or flood easements, and (2) follow up with capital improvements to modify levees and retrofit revetments so that the river is reconnected to its floodplain. This will increase flood conveyance and storage as well as accommodate sediment deposition. Returning the lower White River to a more naturally functioning floodplain will also improve aquatic and wildlife habitat. Levees will be reconstructed away from the current active channel, large wood structures will be installed to disperse erosive flows and provide complex habitat, and native vegetation will be planted to eventually provide a healthy riparian buffer. These flood-risk reduction objectives are framed in the 2006 FHMP and are also consistent with recommended salmon habitat recovery actions present in the WRIA 10/12 Salmon Habitat Protection and Restoration Strategy (Pierce County 2008).

1.5. Performance Measures

Performance measures are the specific outcomes that will be used to determine whether the project actions were successful at meeting the project goals and objectives. Performance measures are listed below.

Implementation Monitoring:

- The constructed project matches design specifications and meets or exceeds performance standards defined by regulatory requirements.

Effectiveness Monitoring:

Project Goal 1:

- Increase in natural channel movement and planform change
- Increase in juvenile salmon rearing and holding habitat, such as side channels, backwaters, and low-velocity margins
- Increase in juvenile salmonid abundance within the project area
- Increase in large wood recruitment within the project area
- Increase in adult salmon migration and holding habitats, such as deep pools
- Increased floodplain inundation area during flood events
- Riparian forest regeneration and increased riparian buffer along project margins

Project Goal 2:

- Equal or lower water surface elevations during flood events
- Equal or lower channel migration risk (outside of project area)
- Installed hardscape project elements such as setback levees, revetments, and log structures are intact and stable

Project Goal 3:

Project Goal 3 focuses on minimizing or avoiding the need for remedial actions, as well as maximizing cost-effectiveness and tailoring the project to meet the needs of stakeholders. Cost-effectiveness will be assessed by comparing this project to other similar floodplain reconnection projects, and stakeholder involvement will be an ongoing process whereby relevant stakeholders (e.g., cities, Tribes, permit agencies, etc.) will be involved in the design and review process. Therefore, the only measurable target under Goal 3 will be whether remedial actions (e.g., levee/revetment repair, engineered log jam repair, sediment management, etc.) are required.

1.6. Design Criteria

This section will be revised in the final Monitoring Report to include:

- *A list of primary design criteria*
- *A list constraints with the greatest influence on design*

1.7. Key Assumptions and Uncertainties

An assumption in this approach to floodplain reconnection is that alleviating constraints on impaired biophysical processes will result in a ‘return’ to conditions that more closely resemble a pre-impact state (or trajectory). This implicitly assumes that the floodplain ecosystem has a single equilibrium point. If so, conditions should move steadily toward equilibrium conditions over time. Project goals and trajectories can therefore be stated precisely because the system dynamic is predictable. Projects are typically designed to accelerate system development along a natural trajectory to reach desired conditions as quickly as possible. This approach is generally reliable at large scales (entire reaches or valley segments, for example) where ecological conditions are strongly regulated by internal negative feedbacks (for example, competition for light, water and nutrients among riparian plants could result in predictable changes in community composition with time since restoration was completed).

However, floodplain ecosystems also exhibit non-equilibrium dynamics (and multiple stable states), especially at the scale of individual habitat units or patches in which the physical environment is highly variable. In this case, future conditions are relatively unpredictable due to the influence of external factors such as climatic variation (droughts and floods), chance dispersal events or limitations, or the biological legacies of past events (landslides, cutoffs, and logjams, for example). The system cannot be expected to trend toward a single condition. If the system being restored is assumed to exhibit persistent non-equilibrium dynamics, restoration goals should be relatively broad and the substantial uncertainty in the outcome should be acknowledged (Suding and Gross 2006). In this case, the unpredictability of future conditions does not constitute a restoration failure. Rather, it is an explicit recognition of the natural dynamics of the system. Success is achieved by restoring the natural dynamics and (variable) ecological attributes of a system that was previously forced into a stable (undesirable) state by human pressures.

These alternative views can be viewed as complimentary, rather than mutually exclusive, at the scale of entire reaches or valley segments and at time scales spanning multiple decades. At these scales, floodplain rivers seem to exhibit a shifting mosaic steady state, where conditions (for example, the composition of the landscape and biological communities) and processes (bank erosion, cutoffs, vegetation establishment) fluctuate over time but are relatively predictable and increasingly stable over the long term. Project goals can therefore rely on specific predictions of the type and composition of communities and processes that should result, but acknowledge that their specific distribution, sequencing, and extent are largely unpredictable and should vary over time (Suding and Gross 2006). Quantitative benchmarks should be interpreted in a fashion consistent with the issues described here.

Sources of Error
This monitoring study – like all studies – will be affected by sampling error and measurement error, which in combination determine the total study error. The total study error limits the estimation accuracy of indicator metrics and the decisions that are based on their interpretation.

The primary sources of potential sampling error in this study are related to the inherent variability in the landscape, and to sampling design. Some aspects of this study (e.g., wood budget) imposed a patch type classification scheme on a continuum of riparian conditions. Stratification necessarily oversimplifies the true variation in nature. Additionally, the patches were assumed to be internally homogenous – representative of that patch type – though estimates are certainly influenced by the inclusion of transitional areas between patches and other kinds of edge effects. Logistical constraints limited the sample size and therefore the precision with which the average conditions of patch types can be characterized. Forest structure and soil characteristics in existing stands must be assumed to be representative of the same patch type during baseline conditions.

The primary sources of measurement error will be related to the accuracy and precision of field measurements, aerial photo mosiacs, photo-interpretation, and maps based on heads-up digitizing. Measurement error involves both observer bias and instrument precision. These sources of error will be minimized as much as possible. Some spatial error is also likely present in the aerial photo mosaics used as base maps for planform maps of channel and forest features. Additional error is introduced by potential misinterpretation of visual cues when mapping features through heads up digitizing. Sources of measurement error related to data handling – for example, transcription error – will be avoided by entering field data in a Pocket PC computer (or similar device) which allow measurements to be downloaded without transcription.

1.8. Project Cost

The Countyline Levee Setback Project has a total estimated cost of $11.3 million (design, acquisition, construction, and permitting). The Right Bank Levee Setback Project is currently in the acquisition phase; design, construction, and permitting costs will be determined during the conceptual design phase.

2.0. Monitoring Strategy

This monitoring plan will help evaluate the effectiveness of two levee setback projects intended to reduce flood risk and improve natural processes that create and sustain productive aquatic habitat.

2.1. Monitoring Purpose

An understanding of natural floodplain processes and baseline conditions is essential for planning river and floodplain restoration projects and for evaluating effectiveness (Pess et al. 2005; Ward et al. 2001). Because the science of floodplain restoration is still in development, restoration actions should be viewed as experimental manipulations linked to explicit hypotheses (Pess et al. 2005). The purpose of this monitoring plan is to evaluate whether two large-scale floodplain reconnection projects on the Lower White River effectively meet the stated project goals and objectives and are able to test the monitoring hypotheses. The purpose of this monitoring plan includes:

1. Ensure the projects match design specifications (Implementation Monitoring),
2. Determine whether levee setback project actions are producing the intended effects on habitat conditions, watershed processes, threatened fishes, and flood risk (Effectiveness Monitoring), and
3. Improve design, construction, and maintenance practices using monitoring results (Adaptive Management).

2.2. Intended Audience

The primary audiences for implementation and effectiveness monitoring results include:

1. King County staff – Results will be shared to inform future project design, construction, and monitoring protocols.
2. Regulatory agencies – Monitoring results will allow regulatory agencies to determine whether performance standards are being met, as well as inform review of future projects with similar elements.
3. Funding agencies and project stakeholders – Monitoring results will provide funding agencies and project stakeholders with the information necessary to determine whether funding agreements are being followed, as well as to evaluate the effectiveness of the project at meeting funding priorities.
4. Scientific community – This study will add to a growing body of research into the effects of large-scale floodplain reconnection projects on channel processes and habitat conditions, as well as the efficacy of levee setbacks for flood risk reduction in depositional rivers.

2.3. Key Questions

This study is designed to answer four key questions related to project implementation and effectiveness:

Has project implementation within the Countyline Reach:

1. Met the design specifications of the projects?

2. Improved riverine processes and functions to the lower White River and its floodplain within the project area?
3. Reduced or maintained current levels of flood risk outside of the project area?
4. Reduced the need for remedial actions within the project area?

2.4. Monitoring Objectives

The following study objectives are included to accomplish this goal:

1. Manage construction to ensure projects are built and restored according to design specifications.
2. Measure channel processes, aquatic habitat, riparian processes, fish and amphibians in study reaches before and after project implementation. Sample within a control reach if applicable.
3. Perform regular facility inspections (annual and post-flood) to identify structural issues.
4. Monitor the project site during floods to assess project performance and water surface elevations.
5. Analyze data at various scales and in the context of other studies.
6. Report on findings to permit agencies and other interested parties. Make results available to the public on the King County project website.
7. Utilize findings to improve project design, construction, monitoring, and maintenance.

2.5. Hypotheses

Monitoring hypotheses are designed to answer the key questions related to project implementation and effectiveness. Several monitoring hypotheses are proposed (Table 1).

Table 1. Monitoring hypotheses and objectives.

Category	Hypothesis		Monitoring Objective
Project Implementation	PI1	Project is built and restored according to design specifications.	Manage construction to ensure projects are implemented according to design specifications.
Channel Dynamics	CD1	Channel meandering (movement, sinuosity, and braiding) will increase.	Analyze channel movement using digital airphotos.
	CD2	Increased scour and deposition will cause streambed and floodplain heterogeneity to increase.	Map changes in streambed and floodplain elevation with maps generated from LIDAR and cross-section surveys.
	CD3	The distribution of potential spawning sediments may shift upstream or downstream, but the overall extent will not decline.	Quantify and map longitudinal changes in substrate particle size distributions.
Aquatic Habitat	AH1	The area of slow-water rearing habitat will increase.	Map slow-water edge habitat.
	AH2	Channel width, length, branching and associated edge habitat will increase.	Quantify channel dimensions, and edge habitat from photos and elevation maps.
	AH3	Logjams will increase in frequency and size due to elevated wood retention, and the number of large isolated pieces retained will increase.	Tally and measure logjams and large isolated pieces of wood, tag key pieces to estimate retention.
Riparian Processes	RP1	Forests will erode at faster rates, resulting in increased wood delivery to the river.	Quantify forest erosion rates.
	RP2	Tree regeneration will occur naturally in both planted and unplanted areas.	Quantify the rate of tree regeneration in forest plots.
	RP3	Invasive plants will invade restored areas more slowly than non-restored areas.	Map invasive plant patches.
Fish & Amphibians	FA1	Juvenile salmonids will occupy low velocity rearing habitats resulting from floodplain reconnection actions and their density will increase proportional to habitat availability.	Map habitat types and conduct fish surveys to estimate fish occupancy.
	FA2	Lentic amphibian breeding habitat will decrease, as will the occupancy and abundance of amphibians within the project areas.	Survey amphibian egg masses to determine lentic breeding amphibian species richness, relative abundance, and estimated egg mass mortality.
Flood Risk	FR1	Installed elements (ELJs, setback levees, etc.) have remained stable over time.	Conduct annual (low flow) and post-flood inspections.
	FR2	Flood risk outside of the project areas has decreased or remained the same.	Conduct flood patrols and monitor water surface elevations. Survey channel cross-sections, calculate changes in sediment volume and rates of deposition, and model changes in flood surface elevations.

2.6. Indicators

Indicators, or evaluation metrics, are proposed for each hypothesis (Table 2). These indicators are intended to be used for effectiveness analyses (comparisons between time periods) and interpretation of the overall project success. Indicators are not proposed for project implementation monitoring.

Table 2. Indicators for evaluating project effectiveness.

Hypothesis	Indicator (Evaluation Metric)	Units
CD1	Median channel movement rate/bank retreat for each mechanism and direction (e.g., meandering to the right)	m yr^{-1}
	Sinuosity	Channel length:reach length (dimensionless)
	Braiding index	B_r
CD2	Channel dimensions	Width, mean depth, cross-sectional area, wetted perimeter, hydraulic radius, max depth, bed width, thalweg elevation, average bed elevation
	Channel geometry	Width:Depth, dmax/d, asymmetry
	Bank erosion	ha $km^{-1}yr^{-1}$
	Bar growth	m^3 $km^{-1}yr^{-1}$, ha $km^{-1}yr^{-1}$
	Scour hole growth	m^3 $km^{-1}yr^{-1}$, ha $km^{-1}yr^{-1}$
	Slope	m/m, ft/ft (dimensionless)
CD3	Longitudinal extent of suitable spawning substrate; (where D_{50} is approximately 22-48 mm diameter)	km
	Substrate size by river kilometer, overall	Max, D_{84} D_{50} D_{16}.
	Percent fines: Area <12% fines, Area 12-17% fines, Area >17% fines	Average of sampled locations (m^2 km^{-1})
	Embeddedness: Area dominated by a) gravel/cobble with <20% embeddedness; b) Gravel/cobble subdominant 20-30% embedded; c) sand, silt or small gravel dominant or >30% embedded	Average of sampled locations
AH1/AH2	Secondary channels	m km^{-1}, ha km^{-1}
	Side channels	m km^{-1} ha km^{-1}
	Backwaters	m km^{-1} ha km^{-1}
	Bar edge	m km^{-1} ha km^{-1}
	Bank edge	m km^{-1} ha km^{-1}

	Pools and ponds (various types)	No. km^{-1}, ha km^{-1}
AH3	Logjams and key logs	Location, size, m^3 km^{-1}, No. km^{-1} (by size)
RP1	Erosion rate for each vegetated patch type	*k*
	Average area for each vegetated patch type	ha km^{-1}
	Wood recruitment rate by volume	m^3 km^{-1} yr^{-1}
RP2	Wetted channel colonization rate	*k*
	Bar colonization rate	*k*
	Seedling density in pioneer bars and developing floodplains by species	No. ha^{-1}
RP3	Area colonized by invasive plants	ha km^{-1}
	Invasion spread rate	ha km^{-1}yr^{-1}, percent change
FA1	Relative abundance of juvenile salmonids in discrete habitat types	Percent of total
FA2	Amphibian species richness	No.
	Egg mass abundance by species	Percent of total
	Egg mass mortality	Percent of total (per egg mass)
FR1	Structural integrity of installed projects elements	Scour/erosion, slumps, dislodged or missing logs or rock
FR2	Water surface elevations	Direct observations, hydraulic model results
	Channel capacity	Deposition rates, cross-sectional area

2.7. Design

The study reach will be monitored before and after project implementation to measure changes in physical and biological process as well as to assess the ability of the project to meet its stated objectives. A control reach immediately upstream between the R Street SE and A Street SE Bridges in Auburn (will be used where appropriate to account for variability related to environmental fluctuations (Roni et al. 2005).

3.0. Monitoring Work Plan

3.1. Sampling Methods and Protocols

Monitoring techniques will focus on classic floodplain restoration elements (channel migration, side channel formation, habitat use, etc.), but also on elements that are unique to the Lower White River. The White River supports the only population of spring Chinook salmon in South Puget Sound. Therefore, project design will be explicitly linked to habitat requirements of juvenile spring Chinook and the limiting factors outlined in the WRIA 10/12 Salmon Habitat Protection and Restoration Strategy (Kerwin 1999; Pierce County 2008). Also, because the White River carries such a high sediment load that is largely deposited in this reach of the river, monitoring will focus on sediment deposition and its impacts on project effectiveness (both in terms of flood risk reduction and habitat benefits). Finally, both levees have wetlands on the landward side that are currently cutoff from regular flood inundation. Therefore, amphibians and vegetation will be monitored to determine the relative benefits and costs associated with project implementation.

Channel Dynamics

River and Channel Pattern

The river channel may adjust to restoration by moving laterally and reshaping the pattern of the river across the reach and within the channel. Changes in river and channel patterns strongly affect the physical habitat template for salmonids and riparian forests. River pattern will simply be mapped by interpreting ground surface elevations and aerial photos. Airphoto analysis will be used to quantify the geomorphic processes that lead to planform adjustment following restoration.

Changes in river and channel pattern may result from increases in the rate and frequency of meandering, neck and chute cutoffs, large scale avulsions or from the reoccupation of old channels resulting in a new main channel or secondary channel (anastamosing). These processes will be measured from changes in the location of the wetted channel centerline as indicated by digital airphotos within fixed belt transects extending across the 100 year floodplain. Analytical procedures will follow Latterell (2008); in which movement of the channel centerline between consecutive years is quantified along vectors spaced at intervals scaled to channel width. The result will be annualized estimates of channel movement, by mechanism, averaged within belt transects oriented perpendicular to the valley axis.

Cross-sectional Form

The river channel may also adjust to restoration by adjusting the width and depth of the bed. Changes in channel size and shape, in cross-section, will be measured from ground surface elevation maps (and airphotos) in each sampling year at channel cross sections, oriented perpendicular to the main axis of flow.

Bed Configuration & Substrate

In addition to adjusting its pattern and cross-sectional form, the river may respond to restoration by adjusting its bed configuration. Adjustments in the riverbed, such as the type, number, size, and location of bars, as well as the depth and uniformity of the thalweg, indicate where localized changes in sediment transport have occurred in relation to constructed or removed features. Changes in grain size affect their suitability of bedforms as habitat for insects, trees, and spawning fish. Accordingly, bedforms will be mapped and classified using ground surface elevation maps and aerial photos: point bars, alternate bars, transverse bars, and mid-channel bars (Knight 1998).

Changes in bedform grain size will be quantified by sampling surface sediments using a modified Wolman method (Wolman 1954) adapted from (Booth et al. 1991), comparable to traditional (volumetric sampling) methods that sieve by weight (Kellerhals 1971, Church 1987, Diplas 1988). Pebble counts will be conducted on each barform, at consistent locations that represent materials in transport in the main part of the flow. On point bars, pebble counts will be conducted on the upstream half of the bar, midway between the upstream end of the bar and the mid-point (in planform view). On mid-channel bars, pebble counts will be conducted from a starting point roughly 25 m downstream from the tail of the riffle associated with the bar head. For both types of bars, a 40-50 m transect will be centered on the starting point and extended parallel and adjacent to the wetted channel margin (during low to moderate flow). Two technicians will walk in opposite directions from the starting point, selecting grains with the blind heel-to-toe method, using a sharpened pencil to choose individual grains for measurement, to reduce bias against small grains. The intermediate diameter of each grain will be measured to 1 mm until each technician has sampled 25 grains. They will then turn toward the starting point, move laterally one to two meters (creating a parallel offset transect) and sample an additional 25 grains each, until a total of 100 grains have been measured. The spatial coordinates of each sample will be recorded with a GPS.

Aquatic Habitat

<u>Edge Habitat</u>

The primary focus of aquatic habitat surveys will be to determine how the amount, type, and distribution of low-velocity edge habitat (hydraulic refuge) changes with flow before and after restoration. Edge habitats are generally characterized by shallow and low velocity water and fine substrate and have been shown to be important for juvenile salmonids, particularly Chinook (Hillman et al. 1987; Bjornn 1971). This sampling will focus on bars and banks (Beechie et al. 2005). Bank edges are vertical or nearly vertical (either natural or hardened) and typically flanked by mature vegetation (or agricultural fields). Bar edges are shallow, low gradient shorelines and may occur along both unvegetated and vegetated areas.

Edge habitat mapping will be conducted seasonally to correspond with fish sampling. Edge habitat will be classified, mapped and measured with two downriver passes; one along the left bank and the other along the right. The margin of the wetted channel will be mapped on foot by GPS. The midstream (waterward) margin of the edge habitat will be located with a flow meter – where water velocity is approximately <1.5 ft/sec- and the slow-water boundary mapped at multiple points by GPS. Points and water margins will be transferred to a GIS and to permit the area, number, and distribution of low-velocity edges to be quantified for bars and banks, and then plotted against corresponding discharge levels.

<u>Large Wood Storage and Recruitment</u>

Field surveys of large wood will follow methods specified by Montgomery (2008) and Latterell (2012).

Airphotos may also be used to replace or supplement field surveys. Logjams will be mapped as a single unit, and large isolated pieces (i.e., E4s and larger; Montgomery 2008) will be mapped separately. In each case, the point will be given several attributes based on photo interpretation. The trapping location will be noted as mainstem, side channel, backwater, floodplain, or wetland. The physical function of jams and pieces will be noted as: pool scour, bar formation, bank stabilization, flow splitting, meander geometry, and sediment trapping. The ecological functions will be noted as vegetation regeneration, juvenile salmonid cover, juvenile salmonid rearing habitat, and adult holding habitat. The size of each individual piece will be described using the alphanumeric code from Montgomery (2008), ranging from E4 to G7. The river mile location will also be noted.

Riparian Processes

Forest Erosion

Landcover change will be determined from airphoto analysis using existing maps from Collins and Sheikh (200X) as the base layers. Landcover boundaries in existing coverages will be revised and updated in pre-and post project airphotos to determine current landcover compositions. This approach ensures new maps share consistent boundaries and comparable land cover types with previous studies that provide an important historical context for interpreting changes. Landcover maps will be updated manually at a fixed magnification (1:1,000 scale).

A primary focus of this analysis is to determine whether forests are eroding and re-establishing at rates comparable to reference rivers or historic conditions. The turnover rate of existing floodplain forests can be estimated by plotting the fraction of the initial floodplain forest (present at the time of project implementation) remaining intact after 3,5, and 10+ years after restoration (modified from Latterell et al. 2006). Patch specific erosion rates can be determined by subdividing floodplain forests into height classes or landform associations, if desired. An exponential decay model will be fit to each resulting points. The form of the model is:

$$p_{l,t} = e^{-kt}$$

where $p_{l,t}$ is the proportion (ranging from 1.0 to 0.0) of the floodplain forest area remaining intact (not eroded) at time *t* in years (*p* at *t*=0 is 1.0), *k* is the calculated erosion rate constant, and *t* is time in years. The model will be used to calculate the turnover rates of each habitat type (half-life; $t_{0.50} = 0.693/k$, 95% life, $t_{0.95} = 3/k$).

Native and Invasive Vegetation

Vegetation monitoring transects will be established in disturbed areas to evaluate the success of planted vegetation and to establish baseline conditions for estimating the rate at which native trees colonize bare ground. Transects will be established within five strata (four per stratum): naturally-formed gravel bars (GB), constructed depositional bars behind ELJs (ELJ), riparian buffer (RB), off-channel forested areas (OC), and levee slopes (LS). Transects will not cross strata. A photo monitoring point will be established at the beginning and end of each transect looking upstream and downstream along the transect. Some transects in the active floodplain and channel (GB, ELJ, OC) may become inaccessible as channel complexity increased following construction. Reasonable effort will be made to access transects, but if access is unsafe or impossible, a suitable replacement area will be found.

Percent cover trees, shrubs, groundcover, and invasive plants will be measured using circular plots with a 3-m diameter at three locations, the beginning, middle, and end, of each transect. Percent cover will be estimated using Daubenmire cover classes to ensure repeatability of measurements.

Tree regeneration will be measured at five locations along the transect within 1-m^2 quadrats. Trees will be classified by species and seedling versus non-seedling. Five 4-m^2 quadrats will be established at the same locations along the transect. Invasive species will be identified and classified as seedling or non-seedling within these quadrats.

Fish and Amphibians

<u>Juvenile fish use</u>

The study area has the potential to provide valuable rearing habitat for salmonids which is limited in the Lower White River. Fish monitoring will focus on quantifying changes in rearing of Chinook, steelhead, and coho.

Nighttime fish surveys (beach seining) will be conducted in mapped habitat units to determine the relative importance of each habitat type. We will record species composition and relative abundance for each habitat type (near the time of mapping). If it is not possible to sample all of the habitats, then a stratified random sample of habitats will be selected for surveys proportional to the type of habitats that are available in the study reach. Because steelhead, coho, and some Chinook may rear in the White River year-round, a total of four surveys are proposed during each monitoring year; one in each season (winter, spring, summer, fall). Surveys will occur at river stages similar to those chosen for the habitat mapping.

Logistic regression models will be used in each monitoring year to determine which habitat types are important for various fish species and size classes. Additionally, habitat suitability criteria based on frequency analysis will be developed by calculating a frequency histogram (Sturges 1926):

$$C = \frac{R}{(1 + 3.222 \bullet \log_{10} N)}$$

where, C is the optimal interval size, R is the range of the observed habitat variable (e.g. velocity max – velocity min), and N is the number of observations. Bin widths are calculated for each variable, and smoothed using a 3-point mean. Histograms are then normalized, and the suitability curve can be drawn from the distribution. Although habitat quantity will be compared between monitoring years, due to inter-annual variability in fish populations and sampling challenges, there will be no attempt to quantify changes abundance of juvenile salmonids between years.

Amphibian Monitoring

In King County, a wide array of amphibians utilize wetlands during some life stage, with eight native species breeding in lentic habitats[1] (Richter and Azous 2001). Monitoring breeding amphibian populations may provide early warning signs regarding wetland habitat, hydrologic changes, and water quality deterioration, because amphibians are considered sensitive indicators of changes in water regimes, sedimentation, and water quality (Reinelt et al. 1998; Richter et al. 1998; Richter and Azous 2001). The removal or setback of levees on both the left and right banks of the White River are expected to directly impact available open water wetland habitat, potentially adversely impacting lentic breeding amphibians.

Amphibian breeding surveys will generally follow methods outlined by Thoms et al. (1997) modified by Richter and Ostergaard (1999). Survey dates may vary slightly from year to year based on the timing of oviposition, but two annual egg mass surveys will be conducted by two biologists in approximately the first three weeks of March and the second two weeks of April. Rain, high winds, and to some extent overcast conditions will be avoided whenever possible to maximize visibility through the water column. Surveys must be postponed if surface ice is present.

At each wetland surveyed, identify the existing habitat types using the Cowardin classifications (e.g., riverine, lacustrine, palustrine) and estimate the approximate proportion of each one. Surveys will be focused in habitats containing the following three features:

(1) areas with slow moving water (velocity < 5 cm/second)

(2) thin stemmed emergent vegetation

(3) water depths ranging from 0.2 to 0.5 meters

Some areas without all three of these features may be surveyed if they connect or are contiguous to optimal habitat areas.

Surveys will be conducted in the wetlands by wading in shallow water or floating in a small float tube in water deeper than 3.3 ft (1 m) while scanning ahead and to the side to identify any existing egg masses. If there is slight water current, researchers will walk against the current so stirred up sediment does not reduce visibility. If there is no current, surveyors will walk very slowly or use float tubes to avoid stirring up sediment. Egg masses will be identified by species and percent mortality per clutch will be estimated within eight categories (0%, 1-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%, or partially hatched). When observed, larvae, paedomorphs[2], juveniles, and adults will be identified to species if possible, and calling frogs will be noted and identified by call when heard. Red-legged frog (*Rana aurora*) and Northwestern salamander (*Ambystoma gracile*) egg masses will be flagged with colorful string either in the egg mass or on nearby vegetation during the first survey period so that during the second survey egg masses can be recorded as new or repeat observations. At the conclusion of the survey for each wetland,

[1] Lentic refers to still waters such as lakes and ponds.
[2] Paedomorphs retain larval characteristics (such as the retention of gills) into adult life Jones, L. L. C., W. P. Leonard, and D. H. Olson. 2005. Amphibians of The Pacific Northwest. Seattle Audubon Society, Seattle, WA..

notes will be made on a map to indicate any areas with especially high or low concentrations of egg masses.

Survey results can be used to determine species presence, but failure to see a species does not ensure its absence especially for long-toed salamanders (*Ambystoma macrodactylum*), which have eggs that are difficult to find and active periods that are before our survey period or rough-skinned newts (*Taricha granulosa*), which have well camouflaged eggs laid singly on the underside of vegetation. In contrast, egg masses from red-legged frogs (*Rana aurora*), Northwestern salamanders (*Ambystoma gracile*), Pacific treefrogs (*Pseudacris regilla*), or the non-native American bullfrogs (*Rana catesbeiana*) are generally observed using these survey methods if they are present in a wetland.

Results will be compiled to track changes in amphibian species richness, egg mass abundance by species, and egg mass mortality. See Appendix A for descriptions and photographs of amphibian egg masses by species.

Supplementary amphibian data will likely be obtained by trapping methods (minnow trap, fyke net) directed at surveying fish. Amphibians caught or trapped during these surveys will be identified to species, measured, and the habitat location noted contributing qualitative information on amphibian use. These methods are described in more detail above in the fish section.

Flood Risk

<u>Routine Facility Inspections</u>

Annual facility inspections and post-flood damage inspections will be conducted to identify active or potential problems (including damage, maintenance needs, or noxious weeds) that may affect the functionality of a facility, eligibility requirements for federal funding for repairs, or affect a particular reporting requirement such as State noxious weeds reporting requirements.

If a damage or maintenance issue is identified, the inspection identifies next steps to evaluate and address the problem further. The data collected from inspections will make use of GPS field equipment to capture spatial data as well as data in digital format to improve the speed and efficiency of data transfer to the inventory database and allow for direct mapping of key points of interest in the GIS environment. Facility inspection sheets include the following information types:

- Inspectors, time stamp, flow conditions
- Extents of inspection
- Check box for apparent damage and damage description text box
- Geographic location, dimensions, description, severity and photograph of noted damage
- Follow up notifications
- Identification, including geographic location and amounts of invasive vegetation

- Space for other vegetation management and maintenance needs

Facility inspections will be on-going and have a frequency of at least once per year for priority facilities, which include both the right and left bank levees in the Countyline Reach of the Lower White River. Facility inspection records will be stored and made available for access and reporting in the King County River and Floodplain Management Section's Facility Inventory.

Flood Patrol, Channel Capacity, and Water Surface Elevations

This section will be revised in the Final Monitoring Plan to include monitoring methods for flood patrol, measurement of water surface elevations, and use of channel monitoring information to estimate changes in channel capacity and model resulting changes in water surface elevations.

3.2. Sampling Schedule

Sampling intervals differ among variables, but generally follow the intervals below:

- *Pre-restoration:* Field sampling and collection of new data will begin in 2011 and continue in 2012 and 2014. Project implementation on the left bank is scheduled for 2014-2015, and 2016-2017 on the right bank.
- *Post-restoration:* Sampling will be repeated in year one (2016), three (2018), five (2020) and 10 (2026) after implementation. Sampling frequency may be increased as needed to capture substantial changes that occur between regularly scheduled sampling events (e.g., additional LiDAR, orthophotos, and cross sections following a large flood event), and if funding is available.

3.3. Data Management

This section will be revised in the Final Monitoring Plan to include information about which staff are responsible for each element of the monitoring data and where the data will be stored.

3.4. Analytical Methods

Indicators listed in the Table 2 will be used to evaluate the *a priori* monitoring hypotheses. Evaluation of the results will rely on a weight of evidence approach or Bayesian belief network (Marcot et al. 2001; McCann et al. 2006)) that considers the results of univariate and multivariate statistical analyses (where possible), the observed magnitude and direction of changes in key variables, and interpretation of map products and graphical comparisons among time periods. The lack of replication samples in the pre-restoration period will prevent statistical comparison of mean values before and after restoration activities. However, statistical comparisons of mean values will possible for variables that can be measured in historical airphotos. Comparisons of distributions (e.g., X^2-tests) will be useful in some cases, as well.

The focus during the evaluation step should be on drawing on all lines of evidence for a holistic evaluation of restoration effectiveness during the post-restoration period. An overarching question is, "*How have important channel and riparian processes and aquatic habitats changed between baseline and pre-project time periods, and how did these processes and habitats change in response to project activities?*" It is important to note that the White/Stuck River was historically a dynamic system; during the post-restoration period, the specific future values of indicator metrics, and the sequencing and extent of changes, may be largely unpredictable and should vary over time. This unpredictability does not constitute a restoration failure. Instead, successful restoration will be evidenced primarily by changes in impaired process rates; particularly, channel dynamics, streambed changes, riparian patch erosion, and wood delivery and retention, as well as increased edge habitat. These issues are explored further in Section 6.2, below.

3.5. Adaptive Management

The expected outcomes of this study are:

- Quantitative evaluation of the effectiveness of two levee setback and floodplain reconnection projects
- Improved certainty in the outcome of large-scale levee setback projects in mainstem rivers
- Increased understanding of the effectiveness of levee setback projects as a river system management alternative in sediment-rich rivers
- Empirical understanding of how fish, amphibians, habitat, and watershed processes respond to a suite of restoration actions.
- Increased understanding of the appropriateness of specific monitoring methods for evaluating floodplain reconnection project effectiveness.

In general, if the evidence confirms the monitoring hypotheses, the actions taken and techniques employed will be viewed as successful and worthy of application in future (similar) projects and monitoring studies. If the hypotheses are not confirmed, or the evidence remains very weak, we will use the accumulated knowledge to explain (or speculate) why the desired outcomes were not achieved. Lessons from both 'successes' and 'failures' are valuable products from this study; these lessons will be summarized in reports and presentations. The results of this study will likely provide valuable lessons and insights that can be applied to similar projects and studies in the future, and to guide adaptive management decisions.

The project monitoring team is working to develop the Adaptive Management strategy for the Countyline Reach. This strategy will be included in the final monitoring plan.

4.0. Communications Plan

This section will be revised in the Final Monitoring Plan to include the following information:
1. Venues for presenting monitoring results
2. Formats for presenting the information (e.g., report, slideshow, webpage, video)
3. Reporting schedule (with key milestones)
4. How data and reports will be made available for future access and use (archiving)

5.0. Monitoring Schedule and Budget

	Baseline				Year 1	Year 3	Year 5	Year 10	
Category	**2011**	**2012**	**2013**	**2014**	**2016**	**2018**	**2020**	**2025**	**Cost/year**
LiDAR				x	x	x	x	x	**$ 16,000**
Orthophotos				x	x	x	x	x	**$ 12,000**
Cross Sections				x	x	x	x	x	**$ 85,000**
Substrate Characterization				x	x	x	x	x	**$ 80,000**
Fish	x	x		x	x	x	x	x	**$ 21,000**
Slow Water	x	x		x	x	x	x	x	**$ 15,000**
Amphibians	x	x		x	x		x	x	**$ 10,000**
Wood	x			x	x		x	x	**$ 45,000**
Hydrology (Piezometers)	x	x	x	x	x	x	x	x	**$ 7,500**
Weeds		x			x		x	x	**$ 5,000**
Plant Survival					x	x	x		**$ 10,000**
Annual and Flood Inspections					x	x	x	x	**$ 10,000**
Analysis/Reporting		x	x	x	x	x	x	x	**$ 25,000**
TOTAL:	**$98,500**	**$83,500**	**$32,500**	**$316,500**	**$341,500**	**$281,500**	**$341,500**	**$331,500**	

6.0. References

Beechie, T., M. Liermann, E. M. Beamer, and R. Henderson. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Transactions of the American Fisheries Society 134:717-729.

Beechie, T. J., B. D. Collins, and G. R. Pess. 2001. Holocene and recent geomorphic processes, land use and salmonid habitat in two north Puget Sound river basins. Pages 37-54 *in* J. B. Dorava, D. R. Montgomery, F. Fitzpatrick, and B. Palcsak, editors. Geomorphic processes and riverine habitat - Water science and application, volume 4. American Geophysical Union, Washington D.C.

Beechie, T. J., M. Liermann, M. M. Pollock, S. Baker, and J. Davies. 2006. Channel pattern and river-floodplain dynamics in forested mountain river systems. Geomorphology 78(1-2):124-141.

Booth, D. B., K. Bell, and K. X. Whipple. 1991. Sediment transport along the South Fork and mainstem of the Snoqualmie River. King County Surface Water Management Division, Basin Planning Program, Seattle, Washington 98104.

Church, M. A., D.G. McLean, and J.F. Wolcott. 1987. River bed gravels: Sampling and analysis. Pages 43-88 *in* J. C. B. C.R. Thorne, and R.D. Hey, editor. Sediment Transport in Gravel-Bed Rivers. John Wiley, New York.

Collins, B. D., D. R. Montgomery, and A. D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences 59(1):66-76.

Diplas, P., and A.J. Sutherland. 1988. Sampling techniques for gravel sized sediments. J. Hydrol. Eng. 114:484-501.

Galat, D. L., and coauthors. 1998. Flooding to restore connectivity of regulated, large-river wetlands. BioScience 48(9):721-733.

Gergel, S. E., M. D. Dixon, and M. G. Turner. 2002. Consequences of human-altered floods: levees, floods, and floodplain forests along the Wisconsin River. Ecological Applications 12(6):1755-1770.

Heuvelink, G. B. M., and J.A. Huisman. 2000. Choosing between abrupt and gradual spatial variation. Pages 111-118 *in* a. R. G. C. H.T. Mowrer, editor. Quantifying Spatial Uncertainty in Natural Resources: Theory and Applications for GIS and Remote Sensing. Ann Arbor Press, Chelsea, MI.

Jones, L. L. C., W. P. Leonard, and D. H. Olson. 2005. Amphibians of The Pacific Northwest. Seattle Audubon Society, Seattle, WA.

Kellerhals, R., and D.I. Bray. 1971. Sampling procedures for coarse fluvial sediments. J. Hydrol. Eng. 97:1165-1180.

Kerwin, J. 1999. Salmonid Habitat Limiting Factors Report for the Puyallup River Basin (Water Resource Inventory Area 10). Washington Conservation Commission, Olympia, WA.

King County. 2006. Flood Hazard Management Plan: King County, Washington. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, Washington.

Kingsford, R. T. 2000. Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. Austral Ecology 25(2):109-127.

Larsen, E. W., E. H. Girvetz, and A. K. Fremier. 2006. Assessing the effects of alternative setback channel constraint scenarios employing a river meander migration model. Environmental Management 37(6):880-897.

Latterell, J. J., J. S. Bechtold, T. C. O'Keefe, R. Van Pelt, and R. J. Naiman. 2006a. Dynamic patch mosaics and channel movement in an unconfined river valley of the Olympic Mountains. Freshwater Biology 51:523-544.

Latterell, J. J., and R. J. Naiman. 2007. Sources and dynamics of large logs in a temperate floodplain river. Ecological Applications 17(4):1127-1141.

Latterell, J. J., J. Scott Bechtold, T. C. O'Keefe, R. Pelt, and R. J. Naiman. 2006b. Dynamic patch mosaics and channel movement in an unconfined river valley of the Olympic Mountains. Freshwater Biology 51(3):523-544.

Leopold, L. B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Co., San Francisco, CA.

Marcot, B. G., R. S. Holthausen, M. G. Raphael, M. M. Rowland, and M. J. Wisdom. 2001. Using Bayesian belief networks to evaluate fish and wildlife population viability under land management alternatives from an environmental impact statement. Forest Ecology and Management 153:29-42.

McCann, R. K., B. G. Marcot, and R. Ellis. 2006. Bayesian belief networks: applications in ecology and natural resource management. Canadian Journal of Forest Research 36:3053-3062.

National Marine Fisheries Service. 2006. Recovery plan for the Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*). National Marine Fisheries Service, Northwest Region, Seattle, WA.

Overmars, K. P., G.H.J., de Koning, and A. Veldkamp. 2003. Spatial autocorrelation in multi-scale land use models. Ecological Modelling 164:257-270.

Pess, G., S. Morley, J. L. Hall, and R. K. Timm. 2005. Monitoring floodplain restoration. Pages 127-166 *in* P. Roni, editor. Monitoring stream and watershed restoration. American Fisheries Society, Bethesda, MD.

Pierce County. 2008. Salmon Habitat Protection and Restoration Strategy - Puyallup (WRIA 10) and Chambers/Clover Creek (WRIA 12) Watersheds. Pierce County, Lead Entity.

Reinelt, L. E., R. R. Horner, and A. L. Azous. 1998. Impacts of urbanization on palustrine (depressional freshwater) wetlands - research and management in the Puget Sound region Urban Ecosystems 2(4):219-236.

Richter, B. D., J.V. Baumgartner, D.P. Braun, and J. Powell. 1998. A spatial assessment of hydrologic alteration within a river network. Regulated Rivers: Research & Management 14:329-340.

Richter, B. D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology 10(4):1163-1174.

Richter, K. O., and A. L. Azous. 2001. Amphibian distribution, abundance and habitat use, chapter 5. Pages 143-166 *in* A. L. Azous, and R. R. Horner, editors. Wetlands and urbanization: implications for the future. Lewis Publisher, Washington, DC.

Richter, K. O., and E. C. Ostergaard. 1999. King County wetland-breeding amphibian monitoring program: 1993-1997 summary report. King County, Department of Natural Resources, Water and Land Resources Division Seattle, Washington.

Roni, P., M. C. Liermann, C. Jordan, and E. A. Steel. 2005. Steps for designing a monitoring and evaluation program for aquatic restoration. Pages 13–34 *in* P. Roni, editor. Monitoring stream and watershed restoration. American Fisheries Society, Bethesda, MD.

Stanford, J. 2006. Landscapes and riverscapes. Pages 3-22 *in* F. R. Hauer, and G. A. Lamberti, editors. Methods in Stream Ecology. Elsevier, New York.

Stohlgren, T. J., D. T. Barnett, and S. E. Simonson. 2005. Beyond North American Weed Management Association Standards Institute for Invasive Species Science, Colorado State University, Fort Collins, CO.

Sturges, H. A. 1926. The choice of a class-interval. Journal of the American Statistical Association 21:65-66.

Suding, K. N., and K. L. Gross. 2006. The dynamic nature of ecological systems: Multiple states and restoration trajectories. Pages 190-209 *in* D. A. Falk, M. A. Palmer, and J. B. Zedler, editors. Foundations of Restoration Ecology. Island Press, Washington.

Thoms, C., C. C. Corkran, and D. H. Olson. 1997. Basic amphibian survey for inventory and monitoring in lentic habitats. Pages 35-46 *in* D. H. Olson, W. P. Leonard, and R. B. Bury, editors. Sampling amphibians in lentic habitats, volume Northwest Fauna Number 4. Society for Northwestern Vertebrate Biology, Olympia, Washington.

Ward, J. V., and J. A. Stanford. 1995. The serial discontinuity concept: extending the model to floodplain rivers. Regulated Rivers: Research & Management 10(3):159-168.

Ward, J. V., K. Tockner, U. Uehlinger, and F. Malard. 2001. Understanding natural patterns and processes in river corridors as the basis for effective river restoration. Regulated Rivers: Research & Management 17(4):311-323.

Weber, C., E. Schager, and A. Peter. 2008. Habitat diversity and fish assemblage structure in local river widenings: A case study on a Swiss river. River Research and Applications.

Wolman, M. G. 1954. A method of sampling coarse bed material. EOS. Trans. AGU 35:951-956.

Appendix A. Amphibian Spawning Habitat and Eggmass Characteristics[3]

Long-toed Salamander (*Ambystoma macrodactylum*)
In early spring (mid January to early February) look for the eggs of the long-toed salamander in shallow water to 30 cm deep. Mean water depth in one study was 12cm. Long-toed salamanders usually attach their eggs to thin, wispy (less than 1/4 inch diameter grass-like) vegetation just off the bottom, but sometimes are found attached to the bark of submerged trees, fallen leaves, and other detritus along a pond bottom. Eggs are sometimes difficult to find because this species lays eggs singly or in small clutches of 3-25 eggs. Eggs stay loosely attached to substrates but freely move with currents in the water. Their jelly coats are very thin and readily change shape with the current. When picking up eggs, their jelly and egg capsules will sift through partially opened fingers. A positive identification can be made if you can see a double membrane within the jelly surrounding the egg. To see this membrane, it may be necessary to gently wipe sediment or algae from an egg or two. Initially, egg masses are clear, but may later become brownish and dirty from sediment. Eggs do not contain a green symbiotic algae and hence are not green.

[3] Text adapted from Ostergaard and Richter 1999, materials supplied to volunteers in the King County Amphibian Breeding program. Photos by Jo Wilhelm.

Northwestern Salamander (*Ambystoma gracile*)

Northwestern salamanders attach their egg masses to thin-stemmed emergent (1/4-1/2 inch diameter rush-like) plants within the water column and preferably 5-12 inches below the surface. However, if vegetation is only available along the substrate the eggs will be found lower in the water column. Northwestern salamander eggs have 40-150 "countable" brown eggs surrounded by thick "jello-like" capsules that will not flow through the partially opened fingers of your hand. Consequently, these eggs can easily be picked up and looked at. A single egg cluster is approximately the size of an orange. No membranes are evident surrounding the eggs, although distinct egg capsules can be seen within the jelly. Eggs from this species are usually brown or tan and the size of a large pinhead. They can frequently be positively identified by their greenish color (attributable to a symbiotic algae) although red-legged frog and Columbia spotted frogs are sometimes characterized by green color cast. Egg masses sink when removed from vegetation, so don't remove them! Look for this species in deeper water of permanent wetlands because they require two years to metamorphose.





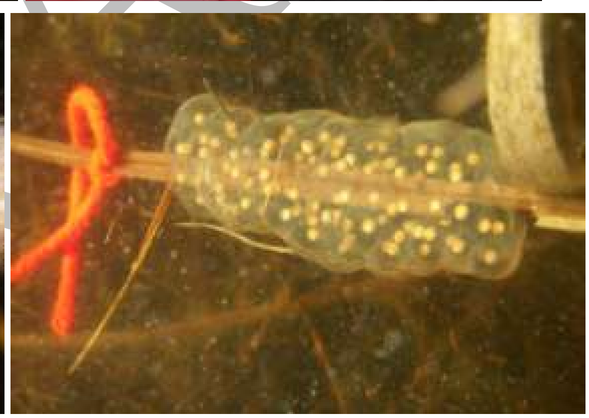
Red-Legged Frog (*Rana aurora*)

Red-legged frog spawn are large, round, lumpy, grapefruit-size egg masses. They are easy to spot because of their hundreds of black eggs. Red-legged frog spawn have uncountable (500-1,500) numbers of small 2-3 mm black eggs. Later in the season they transform into black 8-mm long larvae. Eggs are in a soupy tapioca jelly mass that readily flows through your fingers, especially when the egg masses get older. Where low-density thin-stemmed emergent vegetation is available, eggs are initially attached below the surface, possibly along the substrate. In thicker vegetation, look for new eggs low in the water and attached at the periphery of denser vegetation. In either case, as eggs develop, they float to the surface, and often look like they have small bubbles trapped in them. Large egg "rafts" can sometimes be found when individual clusters break free from vegetation, float to the surface, and become concentrated by current or wind.

Pacific Treefrog (*Pseudacris regilla*)

Pacific treefrogs deposit small, golf-ball size loose clutches (slightly similar to the egg masses of long-toed salamander) of approximately 25 to 100 eggs in shallow water (<25 cm) among thin-stemmed emergents and grass-like species. Eggs of this frog could be confused with long-toed salamander although the frog eggs are much smaller and denser within the jelly, and do not exhibit the double membrane surrounding individual eggs. Fortunately, however, long-toed salamanders are the first to breed in spring, whereas Pacific treefrogs generally spawn later in spring. Therefore you are unlikely to see eggs of both species at the same developmental stage. If the number of eggs in a roundish 1-2 inch cluster that has more than 25 eggs, you can safely identify it as a Pacific treefrog clutch.




Western Toad (*Bufo boreas*)
Toads are among the latest amphibians to spawn in spring of any native amphibian. Only bullfrogs breed later. Western toad eggs are clearly distinguishable by their two clearly definable "pearl-like" parallel strings of eggs. These strings are usually several feet long, have thousands of eggs, and are threaded throughout shallow-water vegetation. They are generally found breeding in deep, permanent water ponds and lakes.

Roughskin Newt (*Taricha granulosa*)
You are not likely to discover eggs of the roughskin newt. Newts spawn in late spring and early summer, and their eggs are attached singly on the underside of vegetation where they are difficult to find. Sometimes eggs are "glued" between the leaves of vegetation so they remain hidden from predators.

Bullfrog (*Rana catesbeiana*)
Bullfrogs are an introduced species that breeds only after warm nights (65 degrees F) in June and July. They spawn large basketball-size clutches measuring over 20-30 cm with thousands (up to 20,000) of very tiny black eggs surrounded by very runny loose jelly. Eggs appear to be attached below the surface but then the jelly expands to the surface. Look for bullfrogs and their eggs in permanent wetlands and stormwater ponds, as this species requires two years to metamorphose.




Appendix B. Equipment Checklist for Amphibian Breeding Surveys

A checklist ensures that suitable equipment is available for the survey and it prevents equipment from being left in the field. Recommended equipment for King County surveys includes the following:

- Field Data Form
- Egg Health & Mortality Form
- Polarized sunglasses
- Pencils
- Marking Stakes
- Colored yarn
- Plastic bags and ties
- Hand lens
- Thermometer
- Small net
- First aid kit

- Deformed Amphibian Survey Form
- Protocols
- Hip boots for shallow wetlands; Chest waders for somewhat deeper water and a small boat or float tube for the deepest water or small lakes
- Identification guide - Amphibians of Oregon, Washington, and British Columbia, by Corkran and Thoms, 1996
- Clear glass salad bowl for underwater viewing
- Compass
- Warm clothing
- Binoculars